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Abstract

FUNDAMENTAL STUDIES OF MATERIALS PROBLEMS IN GAS-COOLED REACTORS

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To maintain reliable and economic operation during the lifetime of a civil nuclear power plant sensibly calls for a sound understanding of the effects of a reactor environment on the properties of its component materials. In this paper examples are given of work undertaken by the C.E.G.B. at its Berkeley Nuclear Laboratories to underwrite the British civil nuclear power programme.

The problems studied fall into three groups:-

those capable of restricting the availability and reliability of operation of a gas-cooled uranium-Magnox reactor. The incidence of fast bursts, currently one in 10^4 fuel elements, could be lowered by at least 100 times by reducing the oxidation rate of uranium. It is shown that a UAl_3 layer formed by the diffusion of aluminium into uranium reduces the oxidation rate of uranium in carbon dioxide by some 200 times without significantly affecting neutron economy.

those capable of restricting fuel element lifetime by setting up a systematic failure mode. Quantitative theories are proposed, supported by experimental evidence, which define a) the conditions necessary to limit distortion when metallic uranium fuel elements are used in a temperature gradient such that both α and β phases are present; b) the circumstances which lead to coalescence of fission-gas bubbles with resultant volume changes in the uranium.

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The creep behaviour of magnesium and Magnox above 250°C is rationalised in terms of a constant activation energy, a variable stress index and a grain size index at stresses above 200 p.s.i. and Herring-Nabarro creep below 100 p.s.i.

those capable of affecting the lifetime of the plant or its operating parameters. The effects of thermal and radiolytic oxidation on the chemical reactivity of nuclear graphite towards air in the absence of fast neutrons is discussed, together with the mechanism of carbon deposition by thermal polymerisation of carbon suboxide: the kinetics of polymerisation and the structure and properties of the polymer are defined.

The electron microscopy of graphite has shown that the dislocation behaviour and structure in graphite are those predicted by conventional theory. It is shown that the detailed dislocation arrangement in polycrystalline graphite accounts for many of the observed mechanical properties. Thermal cycling and low temperature creep behaviour of graphite are predicted. The conditions under which graphite could be expected to support large strains are discussed in relation to the irradiation creep phenomenon. In anisotropic materials there is a continuous irradiation creep due to plastic yielding, whose extent is governed by the relaxation properties of the particular structure. It is shown that in isotropic crystal structure there is only a theoretically practicable transient creep phenomenon due to climb of dislocations and clustering of defects.